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ENVIRONMENT PROTECTION IN THE PRODUCTION AND USE OF ENERGY[x]

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x The views expressed in this paper are those of the author and are not necessarily those of United Nations.

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INTRODUCTION

At local, national and in some cases regional levels, the environmental aspects of energy production and use have become the subject of wide-ranging debate. Environmental awareness and anti-pollution campaigns have affected the formulation of energy policies in many countries, and it has recently been realised that nations are not isolated in this respect: the actions of one country may affect the environment in a neighbouring one. Nowadays, energy policy decisions are dictated less by technological than by social, environmental and political factors.

The production, transportation and use of different sources of energy raise a number of important environmental issues. Among these, questions of the availability and allocation of resources are likely to play as important a role as pollution problems proper. Land and water use, emissions (including thermal discharges) and their impact on ecosystems and human health are but examples of the problems encountered. The 1970's, brought into focus some related socio-economic and geo-political problems. For example, nuclear power development raises problems related to ultimate disposition of nuclear wastes, possibilities of diversion of nuclear material for military purpose or terrorists action and to the public acceptance of this source of energy. On the other hand, concern has been recently voiced at the implications of extensive coal utilization, especially its possible impact on climate. The atmosphere is believed to show a warming due to increasing carbon dioxide emissions. The important question is: what will the regional changes of temperature and rainfall be? Studies with climate models and of climate observations indicate that regional anomalies will probably occur, but the magnitude and impact of these anomalies cannot be reliably predicted at present. The medium and long-term effects of such possible climatic changes are of such fundamental importance that they command serious attention.

The general realization of the finite nature of fossil fuel resources has caused a re-examination of the possibility of using those energy resources which are of a non-depleting nature, and are therefore considered renewable. These energy sources are becoming increasingly important both in developed and in developing countries. In the former strategies for the exploitation of such sources constitute a part of recent policies which aim at reducing the dependence on fossil fuel. In the developing countries, particularly those short of fossil fuel resources, the renewable sources of energy show promise of meeting some of the future energy needs especially of rural areas. Without strong rural development programmes based on decentralized energy sources, urban migration will become torrential, exacerbating the already dire urban problems.

UNEP's pioneer work in the environmental impacts of the production and use of energy has shed a lot of light on this subject, created awareness about environment protection and stimulated interest on the development of tools and methods to control the emissions and releases of the different energy cycles.

In the present paper the environmental impacts of the production and use of energy will not be discussed, instead the emissions and releases of the energy cycles will be summarized. This will be followed by a detail discussion of the methods of controlling these emissions and releases for the ultimate goal of protecting the environment.

In order to facilitate comparison and for convenience the fuel cycles will be divided into stages viz, extraction, transformation, processing, conversion and waste handling. The fuel cycles that are going to be considered here are those used currently or to be used in the near future in developing country particularly in Africa. These are coal, oil, natural gas, nuclear, fuelwood, geothermal, hydropower, wind, solar and biogas.

I. FUEL EXTRACTION

The emissions, releases and occupational health hazards of the extraction stage of different facts are summarized in Table 1. The estimated land and water used are also given in the same table for the production of one TWeh. The reference systems and the other detailed assumptions as the plant size, type and life are in UNEP 1985.

In the following the environmental control of the main emissions and releases of different fuel extraction processes will be discussed.

A. FOSSIL FUELS

1. Coal

Many environmental impacts of coal mining and preparation are unavoidable. For instance, short-term loss of wildlife habitat and agricultural production is inherent in surfact mining. In many instances effective application of existing control techniques and procedures will mitigate the impacts. New control technologies are needed mainly to allow productivity to be improved while meeting recognised environmental objectives.

(a) Airborne Emission Controls

Airborne emissions result from uncontrolled accidental burning of coal piles, refuse piles, and mines: from gases released from piles without burning; and from fugitive dust. Sources of fugitive dust include coal and overburden handling, drilling, blasting and wind erosion. Dust can be controlled during handling by spraying the coal with chemicals or water during loading and unloading, wetting haul roads, and covering haulage equipment. Cyclones and water sprays can be used with drills, and proper placement of explosive delays in blasting rounds can reduce dust by efficient fragmentation. Dust problems may be reduced by the use of electrostatic precipitators fabric

filters, or even well-designed buffer zones. Windbreak can effectively reduce visible dust emissions from wind erosion of coal and overburden.

Gaseous emissions may occur from accidental burning (possibly resulting from spontaneous combustion) and natural releases from refuse banks, mines, and coal piles. Fires can be prevented by controlling air circulation, the concentration of combustible material, and temperature. For preventing fires in abandoned mines, the best techniques including removing excess combustible material and sealing openings to reduce air circulation. Air can be eliminated from refuse piles by compacting and burying them.

(b) Liquid Effluent Controls

The potential sources of water pollution from conventional technologies of coal extraction and preparation are mine drainage, preparation-plant wastewater, and storm water runoff (including refuse and coal-pile leachate) There are several treatment alternatives that apply to all of these sources. although the technique selected and the degree of treatment required, depend on the level of contamination (US/DOE 1981).

Ideally, the best treatment for acid water is to inhibit its formation by preventing oxygen flow to the pyrites. Removing pillars so that the roof can colapse (where subsidence is acceptable) and backfilling and sealing the mine to reduce air flow are the most common ways to minimize acid drainage problems. Control of water flow is also helpful, but is not practical in most cases. There is no effective way to control acid formation in abandoned mines. Alternatives for treatment of mine drainage after its formation include the following (US/DOE 1979). Bcentel Corp 1977.

Chemical precipitation of dissolved solids (usually by pH adjustment).

* Aeration (spraying to entrain air)
* Removal of suspended solids (chemically, by flocculation, or natural settling in ponds)
* Neutralization (chemical pH adjustment)
* Filtration (naturally, through local soil)

Mine drainage is categorized as acid or alkaline. Acid mine drainage generally poses the more serious problem; it commonly requires extensive treatment. Alkaline mine drainage is actually neutral or slightly alkaline and is usually low in toxic metals. Alkaline mine drainage may require only settling to remove suspended solids, and often requires no treatment before discharge.

(c) Control of Water Usage

The two aspects of water usage of primary interest are water consumption by various mining activities and the impact of mining on surface water or ground-water supplies. Water consumption may be reduced by using mine water in the preparation plant, recycling preparation plant or slurry-pipeline water, substituting other liquids for water, and carefully controlling dust-generating activities so that wetting will be minimized.

(d) Land Use Controls

Land is affected by subsidence of underground mines, inadequate reclamation of surface mines, and improper waste disposal. Alternatives that may reduce subsidence impacts include, for example, leaving more or larger pillars, backgilling with preparation plant refuse, and promoting a more controlled subsidence through panel mining.

Inadequate reclamation of surface mine areas may result in the loss of important farmland or wildlife habitat. (US/DOE 1979(b)).

(e) Health and Safety Controls

Barring unforeseen technological advances that would significantly lower the number of miners in mines, the key occupational health and safety objective is improvements in the workplace. The most important of these are miner training, emphasis on safe working practices, and development of equipment that is safer in design and operation. The primary miner health and safety issues in underground mines are roof collapse, explosion and respiratory disease. (US/DOE 1979). Development of new types of equipment, or of safer designs for existing equipment, could lower the number of injuries and deaths. Coalbed methane venting practices may reduce the risk of explosion while simultaneously recovering a significant energy resource. Dust suppression and increased ventilation could reduce respiratory illness.

2. Oil and Gas

(a) Steam Generator Controls

Gaseous emissions from steam generators are the major problem requiring control technology; present controls are the same as those on many industrial and utility boilers today, or are adaptations of them. These will be discussed in details in Chapter IV.

(b) Water Treatment and Disposal

Water treatment may occur as the first step in injection and preparation or as the last step in treating produced water for reuse or disposal. Both produced and source waters can be treated by readily available methods including separators, coalescers, flotation/flocculation gravity separation and softening (Ref. Chapter IV).

Unexpected pollution of underground drinking-water sources by well stimulations can usually be prevented if subsurface stress conditions are identified during the planning stage. When the stress field near the stimulation zone is understood, fracture orientations can be estimated in advance. Such data, along with information on jointing, faulting and aquifer and confining-bed properties at the drilling sites, will prove invaluable for minimizing groundwater pollution.

Impacts from subsurface injection of geopressured brines will occur if injection strata are unsuitable. Careful monitoring of injection pressures, annulus pressures observation-well levels, and other parameters will allow rapid response if well casings unexpectedly fail or confining strata surrounding the injection zone are fractured. Apart from reinjection, the fluids may be treated and used as a source of useful chemicals, such as potassium chloride. Spills or accidental releases of brine in coastal areas could have a significant detrimental impact on wetlands and their ecosystems.

(c) Solid-Waste Disposal

Disposal of solid wastes from drilling operations poses no particular problems; existing landfill or surface distribution techniques may be used. The waste materials for the most part are rock, shale, sand, and clay, whose major environmental impact would be temporary sedimentation of surface waters. Proper grading, drainage and ground cover at the disposal site will keep this problem to acceptable levels. If drilling muds contain chemical or petroleum additives that would pollute surface waters the material can be removed from the site storage pit and reused at other drilling sites, or it can be placed in a "secure" landfill and covered or drained to prevent water infiltration (EPA 1973).

(d) Worker Health and Safety

The most effective mitigation measures for all the hazards of high-pressure and rotating machinery including fires and explosions during drilling and production is a combination of worker training and proper equipment design, which will minimize exposure. In addition, where new or particularly hazardous materials are in use, a program of worker and work environment monitoring could be initiated to measure routine worker exposure and to provide information on any health or safety problems identified.

B. NUCLEAR FUELS

1. Uranium Mining

Solution mining in which the ore is leached in situ from the underground deposit is sometimes practised, thereby alleviating the environmental problems as the need to move large quantities of material, radioactivity of the ore and the solubility of uranium in water (OECD 1984). By careful planning, design and operation of mining facilities and by maintaining adequate ventilation to protect miners from health hazards with radon and radon daughter build up and from dust (UNEP 1980) control of health hazards could be achieved.

2. Uranium Milling

After the uranium has been extracted, more than 90 per cent of the original activity in the ore and virtually all the radium-226 remains in the milling tails (US/DOE 1983). Special treatment of uranium mill tailings before disposal is required. The U. S. Nuclear Regulatory Commission (NRC 1979) has identified two main aims for central technology of mill tailings, viz, to limit release into the air of radon gas and radioactively contaminated particulates, and to limit the leaching of radion-uclides and toxic trace metals into groundwater or surface runoff.

During milling operations, emissions are controlled by keeping the tailings pile-covered with water and spraying dry areas with water or chemicals to form crusts on the surfaces. This reduces radon emanation and wind erosion of dust. NRC has evaluated several options for each of four interdependent aspects of tailings disposal: treatment, disposal location, tailings area preparation and tailings stabilization and isolating cover. Treatment variations identified may include nitric acid leaching to remove (or better isolate in a smaller volume) radium and thorium, separation of the small size fraction (slimes) that contains most of the radionuclides, neutralization or chemical treatment to precipitate radium, removal of nuclides by ion exchange, dewatering, and incorporation in asphalt or cement. Final disposal options include above-grade surface impoundments, open-pit mines, special below-grade excavations, or deep mines. The surface on which the tailings rest may be prepared either by compacting the soil or by using clay or synthetic liners to contain seepage. After emplacement, possible cover materials include (except for deep mines) soil, gravel, stone riprap, clay, or an artificial sealant like plastic or asphalt.

C. RENEWABLE ENERGY SOURCES

Environmental impacts are also associated with the extraction of new and renewable energy sources. Some could be controlled as the brine in the case of Geothermal energy which should be re-injected or disposed of adequately. Others have unavoidable impacts as the construction of dams in hydropwer and the use of land in fuelwood and biomass. Because the extraction and processing stages, if any, are usually in the case of new and renewable energy sources associated with the conversion stage this will be discussed in connection with the conversion stage (Chapter IV).

II. FUEL PROCESSING

The emissions, releases and occupational health hazards of fuel processing stage of different fuels are summarized in table 2. The figures are normalized for the production of TWeh. Following is a discussion on the environmental control aspects of this stage.

A. FOSSIL FUEL

1. Coal

The physical benefication techniques associated with coal cleaning are capable of removing up to 40-50 per cent of the sulfur and 65-75 per cent of the ash contained in the raw coal (Ferrel 1979).

(a) Airborne Effluents

Air pollutants created are fine coal dust, ash, NO_x and SO_x resulting from combustion of coal used to supply the hot gases for coal drying. Air pollution can also arise from burning of refuse piles at coal preparation plants which have caught fire as a result of spontaneous combustion. This can be avoided by preventing oxygen from reaching the carbonaceous material, by reshaping the pile to avoid steepy sides and by covering the pile with soil and vegetation (UNEP 1980).

(b) Liquid Effluents

The liqued effluent produced is called blackwater and contains suspended coal fines.

Black-water is usually sent to a tailings pond where the solids are allowed to settle and then clear water re-circulated. Closed water circuits

have grown in popularity because they eliminate discharge to streams and reduce make-up water.

(c) Solid Wastes

This consists of coarse and fine refuse. Pollution can be controlled by proper reclamation to prevent seepage and divert seepage from the piles to settling ponds where suspended solids and other pollutants can be retained and treated.

2. Oil and Gas

(a) Airborne Effluents

These consists mainly of SO_x, NO_x particulates, hydrocarbons and CO. The control of these emissions will be discussed in Chapter IV.

(b) Liquid Effluents

These wastes are readily treatable with a combination of in-plant controls and treatment techniques and end-of-pipe treatment (UNEP 1980). The last consists mainly of primary separation of oil and solids and neutralization, followed by biological treatment using activated sludge systems, aerated lagoons or oxidation pond.

B. NUCLEAR FUELS

Since nuclearfuel processing is being accomplished mainly in developed countries only brief methods of environmental control will be given below.

1. Uranium Hexafloride Production

In the hydroflour process, the final residue is packaged and buried as low activity solid wastes. In the wet process, the stream which may contain substantial disolved solids (radium-226, Thorium-230 and about 0.2 per cent of the uranium processed) is neutralized and imponded in a retention pond.

Disposal of this effluent is a major problem associated with the wet process. Scrubber effluents of both the hydroflour and wet processes are treated with lime to precipitate flouride in the settling ponds for packaging and burial as calcium fluoride.

2. Uranium Enrichment

The main airborne emissions of the uranium enrichment process are SO_x, NO_x, CO, HC, particulates and uranium-234, 235 and 238 nuclides. Methods of controlling this pollutants will be discussed in details in Chapter IV.

On the other hand the concentration of chemicals in the liquid effluent undergoes considerable dilution before reaching the receiver water (UNEP 1980).

3. Fuel Fabrication

(a) Airborne Effluents

Nearly all of the airborne chemical effluents result from the combustion of fossil fuels to produce electricity to operate the fabrication plant. This will be considered in Chapter IV. Apart from these pollutants flouride is the only significant chemical gas emission from the fabrication process. This could be effectively removed from the air effluent streams by scrubbing and filteration systems.

(b) Liquid Effluents

Nitrogen compounds, which is the most significant chemical species in liquid effluents, is combined with water from air scrubber systems and treated with lime to form a calcium fluorine precipitate which is filtered and stored on site.

The dose commitments to workers and public from fuel fabrication are very low and it is unlikely that the fuel fabrication activity would increase levels of exposure (UNSCEAR 1977).

C. RENEWABLE ENERGY SOURCES

Most of the new and renewable energy sources has no processing stage. Cycles with processing stages, such as biomass will be included in the conversion stage.

III. TRANSPORTATION OF FUELS

Table 3 shows the summary of the environmental impacts of fuel transportation.

A. FOSSIL FUELS

1. Coal

To reduce community disruption, delays and accidents from unit trains, grade separations or rerouting of track around populated areas are alternatives. Rerouting of track away from communities will also result in reduced noise exposure.

2. Oil

Marine transportation is the most important mean of transporting oil. There is a wide variety of marine ecosystems which could be affected by marine transportation of oil (UNEP 1980). The lethal effect of oil depend on its concentration and on the length of time an organism was exposed to it. When an oil spill occurs, several options exist to deal with it:

(a) Contain and remove it

(b) disperse it

(c) burn it

(d) leave it

(e) a combination of these.

Selection of the most suitable technique or techniques depends on the circumstances of each spill. Preventive measures are of course usually more effective.

3. Natural Gas

Natural gas is usually transported by pipelines

The potential environmental impacts of pipeline construction are well known. On the basis of the experience gained extensive body of requirements and regulatives has been developed and implemented in many countries. These include preliminary analysis and impact assessments, desirable construction standards (erosion control, etc.) and required operating standards and practices (pipeline safety etc.).

B. NUCLEAR FUEL

The most hazardous waste shipped by the commercial nuclear power industry is spent fuel. This material is transported in massive stainless-steel casks. Lead or depleted uranium is used to provide shielding from

penetrating radiation. Designs requirements are very severe. A cask must be able to withstand (1) a free fall from a height of about 10m onto an unyielding surface with the package landing in such a position as to do the most damage (2) a free fall from a height of 1m onto a in-diameter steel plunger long enough to do maximum damage with the package in the most vulnerable orientation (3) exposure for 30 min to a free reaching a temperature of at least 790°C and (4) total immersion in water for 8 hr. It must also be able to withstand the pressure of 15 m of water depth without any leakage. Those accident test conditions represent the damage that a package might incur in a severe transportation accident - for example, an accident in which a truck collides with a bridge pier, crashes through a guardrail rolls down a rockey embankment and falls into a river: or an accident in which a train derails, railcars tumble around, several tank cars catch fire a propane tank car explodes, and firemen pumps water into the burning debris (US/DOE 1977).

C. RENEWABLE SOURCES OF ENERGY

Transportation of fuelwood may impost similar a health hazards as those of coal transportation hence similar environmental control measures should be valid for fuelwood.

IV. CONVERSION TO ELECTRICITY

The summary of the emissions, releases and health hazards of the conversion process is given in Table 4 for the production of TWeh. The environmental control aspects of this stage is given below in some details.

A. FOSSIL FUELS

1. Airborne Emissions

(a) Particulate Control

Particulate emissions are controlled with electrostatic precipitators baghouses and scrubbers. Electrostatic precipitators have been used for particulate control in coal-fired boiler applications for over 40 years but baghouses are now being considered for small boilers, low-sulfur coal applications and possible future applications in which a 10 per cent capacity limit must be met. Conventional scrubbers are less attractive economically because of high operating (energy) costs (US/DOE (1978). Electrostatic precipitators collect over 90 per cent of the fly ash in flue gas. The use of baghouses (fabric filters) has received recent attention for low-sulfur-coal applications, for which electrostatic precipators are less efficient. Performance data are limited but baghouses are generally considered to be over

99 per cent efficient. A third method is wet scrubbing, which may be used for the removal of particles alone but is more commonly used for removal of both particles and sulfur dioxides.

(b) Sulfur Dioxide Control

The principle of operation of a lime/limestone flue gas desulfurizing system is that sulfur dioxide is absorbed and reacts with dissolved alkaline species from limestone or lime. The reaction product, calcium sulfite or sulfate, is separated as a wet sludge that must be dewatered and further treated to stabilize it before it can be disposed of. Lime limestone systems can remove more than 90 per cent of the sulfur dioxide. Greater efficiency can be obtained with additives such as magnesium oxide and organic acides. One advantage of this process is that more than 90 per cent of the particles are also removed.

A second throwaway process currently in use is the sodium alkali process. It uses either dry sodium alkali or a wet scrubbing solution. The wet process uses sodium hydroxide, sodium carbonate, or sodium bicarbonate in a wet scrubber or spray dryer: the dry process uses sodium bicarbonate alone or with sodium carbonate. Wet scrubbing is up to 99 per cent efficient, and dry scrubbing is 60 to 95 per cent efficient, depending on the temperature of the alkali and the sulfur dioxide and how long they are in contact. Both processes are simple and use little energy.

The major disadvantage is the disposal of waste products, which are high in sodium salts. (De Vitt et al 1980).

(c) Nitrogen Oxide Control

The oxidation of nitrogen compounds in the coal products "fuel nitrogen oxides", which account for 50 to 90 per cent of the total nitrogen oxides produced by coal combustion. Most of the advanced combustion concepts and modification techniques are directed toward preventing the formation of fuel nitrogen oxides. A fuel-rich initial combustion zone is established in which the fuel nitrogen can be oxidized to molecular nitrogen, rather than to nitric oxide. Thus, all of the combustion modification techniques except flue gas recirculation (FGR) depend on reducing the availability of oxygen in the primary combustion zones.

Combustion modification techniques such as low excess air firing and staged combustion have been shown to be effective in reducing nitrogen oxide emissions from coal combustion. In low excess air firing, the unit operates at a reduced level of total comoustion air flow while maintaining acceptable flame and furnace conditions. There are three methods of staged combustion:

* Biased or off-stoichiometric firing: the air/fuel mixture in the boiler is stratified and part of the combustion air is diverted outside of the initial fuel/air mixing zone.

* Burner-out-of-service operations: the fuel flow to an individual burner is out (while maintaining the air flow)

* Overfire air ports: part of the combustion air enters by ports above the burner to generate fuel-rich conditions at the burner.

In flue gas recirculation, gas is taken from the exhaust stream and re-introduced in the furnace. This technique has often been used for steam temperature control: however, few coal-fired units use flue gas recirucla-tion (Martin et al 1974).

Both nitrogen oxide production and the effect of combustion modifica-tions in reducing it depend on how the furnace is fired. While modification techniques can significantly reduce nitrogen oxide emissions, more advanced concepts, such as new burner designs (which can be retrofitted onto existing units) or flue gas treatment, are required to achieve very low levels of nitrogen oxides.

2. Water Pollution Controls

Wastewater handling and treatment practices vary from plant to plant. They depend on local regulations and are closely tied to solidwaste handling practice.

(a) Cooling-Tower Blowdown and Once-Through Cooling-Water Discharges

Thermal pollution caused by the discharge of once-through cooling water directly to a receiving stream is another area of concern. It can be re-duced by the use of "helper" systems, which remove a portion of the heat before the effluent is discharged. Two examples are long discharge canals and ponds with floating powered spray modules (El Mahgary (1971)). The problem can be eliminated altogether by the use of closed (recirculating) systems employing cooling towers or ponds. Removing dissolved solids from wastewater is difficult. One potential treatment for controlling them is lime precipitation/sedimentation which is effective in removing chromium and zinc. The disadvantages of this process are an increase in the hardness of the water, scale formation on plant equipment, difficulties in dewatering or disposing of resulting sludge and a slow reaction of the lime.

(b) Controls for Water Discharged from Solids-Handling Operations

Pond overflow-water discharged from solids-separation devices, and blowdown or discharge from sluicing operations can contain suspended solids, dissolved heavy metals and trace elements, extremely acid or alkaline mate-rial, and occasionally oil and grease. Control methods include direct treatment (such as sedimentation, chemical precipitation and neutralization)

and process changes. Two process changes that eliminate large-volume discharges from once-through wet-ash handling operations are (1) retrofit dry fly ash handling and (2) closed-cycle buttom-ash sluicing. These ash-handling methods are discussed in detail under solid-waste handling and control.

(c) Controls for Metal Cleaning Wastes

Because metal-cleaning wastes are generated only periodically, many plants have them removed by a contractor. Another common practice is to discharge them to an ash pond. Incineration or evaporation of metal-cleaning wastes has increased since its commercial application in 1971.

3. Solid-Waste Controls

As described earlier; the significant solid waste streams from a fossil fuel power plant include fly ash, bottom ash and flue gas desulfurizing sludge.

(a) Handling, Disposal and Utilization of Fly Ash

Both wet and dry methods are used for collecting and disposing of fly ash. It may be collected dry with electrostatic preciptors or baghouses: disposal may be direct, or the fly ash may be added to scrubber sludge to stabilize it. If the fly ash is collected with a wet-collection device such as a venturi scrubber, it is pumped to a pond in slurry form or sluiced with scrubber sludge to a pond (US/DOE 1980).

One of the difficulties that may arise from disposal of fly ash in ponds or land-fills is the leaching of soluble alkali metal salts and trace elements into groundwater and surface waters. Leaching can be managed by proper site selection, such as avoidance of groundwater, and by careful monitoring and the use of pond liners.

The commercial use of fly ash in USA increased from 7.9 per cent in 1966 to 17.5 per cent in 1978. Fly ash is mainly used as a partial replacement for cement in concrete and as an aggregate material in road base and sub-base construction (US/DOE 1980).

(b) Handling and Disposal of Bottom Ash

In general, the ponding and landfill practices and costs described for fly ash are applicable to bottom ash as well. However, unlike fly ash, bottom ash normally does not leach, so ponds used for bottom ash alone do not require lining.

Bottom-ash sluicing/dewatering systems, as well as pond systems, can be operated in a "closed-cycle" configuration in which ash sluice water is sent to collecting hoppers for reuse in sluicing.

(c) Disposal of Flue gas Desulfurizing Scrubber Sludge

The options for flue gas desulfurizing scrubber sludge disposal include direct ponding and de-watering followed by landfilling. In either method, the sludge can be mixed with fly ash, fly ash and lime, or other materials used in commercial fixation processes. If the sludge is predominantly sulfite, it can be oxidized to gypsum before ponding or de-watering. In the case of mixed fly ash and scrubber sludge from a combined particulate and sulfur dioxide scrubber, the options for disposal are ponding, dewatering and fixation followed by ponding or landfilling, (US/DOE 2980). Scrubber slurries can be made into harder, more stable materials by physical treatment (compaction and moisture content control) and chemical treatment (addition of lime, fly ash, or other fixation chemicals).

B. NUCLEAR CYCLE

The discussion in this section will be limited to LWR power plants.

1. Gaseous Radiological Waste Control Systems

The principal source of gaseous radwaste in a BWR during normal plant operation is the noncondensable gas (some of which is radioactive) removed by air ejectors from the main steam condenser. The noncondensable gas is also a source of radiocativity in a PWR when there are leaks in the steam generators. Most gaseous radwaste in a PWR arises from the stripping of (1) the stream of coolant from the primary coolant system to the chemical volume and control system and (2) a coolant bleed to the boron control system. In modern plants, these gases flow through some or all of the following processes to minimize the release of radioactive effluents to the environment (Ron 1976).

* Catalytic recombination of hydrogen and oxygen to form water, which is treated by the liquid radwaste system.

* Delay systems that hold up release of noble gases to allow the short-lived isotopes to decay. Some BWRs use cryogenic distillation systems to separate the noble gases for longer storage.

* Charcoal beds, which adsorb radioactive iodine

* Filters, which remove particulates from the gaseous waste streams.

Other sources of radioactive gases that could be released into the environment from both PWRs and BWRs include valve-packing leaks, pump seal leaks, tank leaks and spills, and spent-fuel-pool gases that escape into the buildings. The

ventilation systems in the containment, radiological waste and auxiliary/fuel buildings are monitored and provided with particulate filters and charcoal adsorption beds. Figures 1 and 2 show typical gaseous radwaste processing systems in a modern nuclear plant (US/DOE 1981).

2. Nuclear Radiological Waste Control Systems

Liquid radwastes at both BWRs and PWRs may be classified as clean (low chemical content) dirty (moderate chemical content), chemical, and laundry wastes. The primary sources of these wastes are summarized as follows (Eichholz 1976).

Clean	Collected equipment drains, Valve and Flange Leakage, Pump seal leakage
Dirty	Floor drains
Chemical	Steam-generator blowdown (PWRs) Laboratory drains Borated reactor coolant (PWRs) Demineralizer-regenerant wastes
Laundry	Detergent wastes from laundries and shower drains

Other than laundry wastes, which have very low activity and are generally discharged directly to the environment after processing, liquid radwastes at modern power plants are reused as makeup water after being processed through one or more of the following effluent treatment systems:

(a) **Demineralizers (ion exchangers).** Demineralizers contain beds of chemically active resin beads that remove ions from solution. The efficiency of ion-exchange treatment of waste streams depends, among other factors, on the type and composition of the liquid, type of exchanger, regeneration method, radionuclides present, type of resin and operating procedures used. Only relatively clean waste can be processed in an ion exchanger because bed exhaustion occurs rapidly for liquids with a high concentration of total dissolved solids.

(b) Evaporators. Evaporators may be used in the dirty and chemical waste streams to concentrate the suspended solids by boiling off the water, leaving behind most of the dissolved and suspended solids. Wastes high in dissolved solids are best processed by this method.

(c) Liquid Filters. Filters are used to remove suspended particulates from relatively clean liquid waste streams. They are employed with other types of waste treatments as a necessary post or pretreatment step in the liquid processing so that other steps will be more effective.

(d) Holdup Storage. Since many radionuclides in liquid wastes have short half-lives they are stored in large tanks for up to several weeks to permit as much decay as possible.

(e) Reverse Osmosis. In osmosis, water flowsfrom a region of low chemical concentration through a permeable membrane into a region of higher concentration, tending to equalize concentrations on both sides. If a reverse force exceeding the osmotic pressure is applied to the high-concentration side, reverse osmosis occurs. This process is used to purify some laundry wastes and to treat some PWR steam-generator blowdown.

(f) Oil Separators. Oil separators are used to remove the oil and grease from dirty waste streams prior to radwaste processing.

From the foregoing discussions of the various liquid radwaste control processes it is evident that no single method is adequate to provide the high purification required before wastewaters can be reused as makeup water or discharged to the environment. In practice, therefore, combinations of methods are employed.

3. Nonradwaste Effluent Control Systems

Chemical and other nonradioactive wastes, such as materials for corrosion control, may have a greater environmental impact than the low-level radioactive material released into the plant's liquid discharge line. This is particularly so in modern plants, which add and concentrate various chemicals in the closed cooling systems. From these, a small fraction of chemical-laden coolant is drained off (blow down) to limit the buildup of chemicals. Some of the various chemical wastes require removal, but most of them are simply diluted and released to the river in concentrations that meet local water-quality standards. Various removal methods, which are employed on a case-by-case basis are: (Eichholz 1976).

(a) Settling Ponds. If blowdown from the cooling towers, makeup water treatment building, or other sources contains a high concentration of suspended material that would exceed local water quality standards, it may be diverted to a pond or basin to allow the solids to settle before being discharged to the local surface waters.

(b) Neutralization Basins. In these basins, waste liquids that are excessively basic or acidic (e.g. demineralizer regenerant wastes) are combined with other chemicals to neutralize them before they are discharged to the local surface waters.

(c) Oil Separators. Liquids drained from the turbine building, the diesel generator building, and other sources that may collect oil or grease are sent through oil separators before being discharged to the common yard sewer drains.

(d) Sewage Treatment Plant. Lavatory and sanitary drain flow is treated in a sewage treatment plant before being discharged.

(e) Cooling Ponds or Towers. Cooling ponds and towers are used to disperse the majority of the thermal heat discharged from the power plant through evaporation, so as to largely avoid the thermal pollution of the surface waters that might be caused by once-through cooling systems. Cooling ponds are used when land is available at a moderate price, since they occupy about 400...800 ha/GWe of installed capacity. When land is not readily available, cooling towers are used. Cooling towers are classified as either wet or dry; in wet cooling towers, heat is disipated by the evaporation of some of the water being cooled: in dry cooling towers, heat is transferred by the flow of air across pipes containing the water. At present, only wet cooling towers are in use at nuclear power plants. Cooling towers are also classified by the means of producing the air flow: This can be a mechanically induced draft, using large fans, or a natural draft, using a tall usually hyperbolic "chimney" to provide a natural updraft.

(f) Intake Structure. Intake structures are designed for low intake velocities and with special traveling screens that minimize aquatic life impingement and shock at the intake to the circulating water system.

(g) Discharge Diffusers. Diffusers are mounted at the end of the common discharge pipe in the local surface water to help mitigate the effects of thermal and chemical discharges to the environment by aiding dilution.

4. Possible Needs for Radiation Control Technology in the Future

Some of the radioactive emissions released to the atmosphere, such as krypton-85 carbon-14 and tritium have long half-lives. They might be emitted in large enough quantities to be of concern as nuclear power expands and as these isotopes accumulate in the biosphere.

Krypton-85 is a chemically inert gas with a half-life of 10.7 years. Present reactors emit from a few to 100,000 curies of krypton 85 per reactor-year, depending on design. The krypton-85 released at a reactor represents a small fraction of the total generated, because most of it is retained in the fuel. Furthermore, the radiation doses resulting from the release of krypton-85 from reactors are minute. Released krypton-85 which diffuses through the atmosphere worldwide appears to have very limited health effects: its global health risk has been estimated to be on the order of 7×10^{-5} death per reactor-year. Krypton-85 is therefore not collected for long-term storage at nuclear power plants (ERDA, 1977).

More krypton-85 is released during fuel reprocessing than during power plant operation. However, even if reprocessing were instituted on a large scale, the dose from krypton-85 would remain a small fraction of the natural background radiation dose.

Some carbon-14 is produced in commercial reactors by neutron-induced reactions in the cooling water and oxide fuel. Although quantities are uncertain it appears that 20 to 30 curies/reactor-year are formed. The fraction of this released during reactor operation is also uncertain: the remainder would be released from the fuel only in case of reprocessing.

Release of about one-third of the carbon-14 during reactor operation (as carbon dioxide gas) would result in a population whole-body dose of about 50 manrem per reactor-year, which has been equated to about 0.01 latent cancer fatality per reactor-year. The radioactivity of carbon 14 is potentially of greater concern than this figure indicates, however since it has a half-life of 5,730 years and is incorporated into living matter. The amount of reactor-generated carbon-14 is minute compared with the 200 million Ci of carbon-14 in the atmosphere from cosmic rays and the 6 million Ci from atmospheric weapons tests. Carbon-14 release from reactors could be reduced using existing technology, if the hazard were deemed to justify the effort (ERDA, 1977).

The health interest in tritium, which has a half-life of about 12 years, primarily concerns whole-body dose. Most tritium from the LWR is released as tritiated water and rapidly becomes diluted and dispersed in the circulating waters of the world. The discharge rate of tritium will increase roughly in proportion to the total power generated. Several assessments, however, conclude that the quantities of tritium likely to be released present no significant hazard to the public. It is expected that for at least the next two decades most tritium in the environment will be the result of nuclear weapons testing and that the total inventory will decline during this period.

C. RENEWABLE ENERGY SOURCES

1. Fuelwood

Currently available systems for industrial pollution abatement include control by system design and pollution-collection equipment. Abatement systems for large wood-fired systems consist primarily of air pollution controls. Current methods for controlling water and solid-waste pollution are generally considered adequate to meet environmental requirements. Information on the costs of environmental controls for wood combustion is not available (Dunwoody, 1980).

In industrial wood-fired systems, particulate matter is the air pollutant of primary concern. Sulfur dioxide removal is usually required only for boilers burning large quantities of high-sulfur coal together with the wood. Adequate

control of nitrogen oxide emissions can be achieved through proper boiler design and combustion practices. (Schwelger, 1980).

For good control of particulare emissions, the design of the combustion system and the fuel characteristics should receive careful attention. Among the most important variables are the following:

*Tree species and logging region.

*Type and amount of fuel burned in combination with wood waste (if any).

*Size distribution of fuel particles

*Ash content of fuel

*Firing method

*Fuel distribution in the future

*Air distribution under and over the grate (if installed)

*Grate heat-release rate

*Furnace heat-release rate, residence time, and upward gas velocity

*Furnace configuration

*Design of the fly-carbon reinjection system

*Amount of fly-carbon reinjection

The above factors should be evaluated in the design stage.

Many types of control equipment can be used for removal of particulate matter from flue gases. These include mechanical collectors, wet scrubbers, bag filters, dry scrubbers, and electrostatic precipitators. (See IV.A).

Particulate-collection efficiency of 99 per cent has been demonstrated to meet proposed environmental air quality regulations. The multiple-cyclone system (connected in series) appears to be one of the several promising methods for meeting both mass emission rate and opacity requirements, however, further research is needed in this area.

At present no controls are available for residential units, although research on clean-burning units is underway. The eventual cost of such units will determine the extent of their general use.

Other wood combustion emissions that may be subject to future controls are carbon monoxide, hydrocarbons and nitrogen oxides. In addition if evidence indicates that airborne POM occurring in occupational and residential settings may be responsible for specific adverse biologic effects in man, emission controls could be implemented for both small and large combustion units.

Another aspect of the air pollution problem is the effect of wood combustion on the indoor environment. The discovery that pollutant concentrations are often higher indoors than outdoors signals the need for further research to determine the magnitude of this hazard. The efforts to control indoor air pollution could affect energy conservation efforts as well as safety and building methods (WHO, 1984).

Controls such as careful forest management and monitoring will be required to mitigate the environmental effects of wood harvesting, handling, transportation, and storage.

2. Geothermal Energy

(a) Control of Airborne Hydrogen Sulfide Emissions

The release points for hydrogen sulfide can be divided into two categories upstream of the turbine (pre-plant emissions) and downstream of the turbine (power-plant emissions). The pre-plant emissions include releases from well-field construction and operations such as drilling, well testing, pipeline venting, venting steam through the stack, and well bleeding while on standby. Sources of downstream emissions depend on the conversion process: they include both the steam condensate and noncondensable gas streams.

About 90 per cent of the total hydrogen sulfide releases can be attributed to the power conversion process itself. Depending on the conversion process, most of the emissions occur either from the cooling tower or from the noncondensable gas ejector system. (Stephens et al 1980).

Some of the technologies for control of hydrogen sulfide in the geothermal industry have been adapted from other industrial processes, such as the removal of sulfur from coal gas. Most of these are not suitable for geothermal application because they are slow or costly, or because of the chemical form of the sulfur waste product. The systems that react chemically with hydrogen sulfide such as the Stretford process, seem to be better candidates for geothermal application than systems that depend on physical sorption.

(i) Upstream Abatement Techniques

Upstream abatement has the considerable advantage that if the power plant must be shut down because of unexpected conditions, the stream can be released through the stack because the hydrogen sulfide content will have been reduced. A second advantage of upstream abatement is that less costly direct-contact condensers can be used instead of surface condensers. The use of direct-contact condensers would allow an efficient secondary treatment to be applied to the cooling water and condensate for removal of residual hydrogen sulfide if required. Also, an online secondary treatment system could serve as a backup abatement system when the primary upstream steam is out of service. An additional benefit of upstream removal of hydrogen sulfide

is the reduction of corrosion effects on the turbine and the condenser and cooling water equipment. Unfortunately, there are no demonstrated commercialscale upstream abatement techniques. (US/DOE 1981).

At present one of the best candidates for upstream abatement is the copper sulfate process. It is suitable both for vapor dominated resources and for liquid-dominated resources using flashed steam (Stephens et al 1980).

The stream converter with a Stretfor unit for hydrogen sulfide abatement is another very promising candidate technology for upstream abatement. The process has been well demonstrated in other applications.

For liquid-dominated resources, the binary conversion system together with total spent-fluid injection offers satisfactory hydrogen sulfide abatement.

(ii) Downstream Abatement Techniques

When downstream technologies are used for the abatement of hydrogen sulfide, the major concern is the partitioning of the hydrogen sulfide between the gas phase and the aqueous phase in the turbine condenser. In addition to temperature, the pH of the condensate is a significant factor. The lower the pH, the more the hydrogen sulfide partitions into the gas phase. The pH of the aqueous phase depends on the quantities of hydrogen sulfide, carbon dioxide, ammonia and boric acid present.

The type of condenser is also important, because more hydrogen sulfide is in the gas phase (at the same pH) when surface condensers are used. In a surface condenser, the steam condenses on tubes and is in contact with only a relatively small amount of condensate. In a direct-contact condenser, the steam encounters a spray of cooling tower water whose volume is about 20 times greater than that of the condensate. This large volume of water and the more intimate contact provided by the spray increase the amount of non-condensable gases that dissolve in the aqueous phase and decrease the amount in the gas phase.

In the Stretford process, the off-gas is scrubbed with a solution containing sodium carbonate, sodium metavanadate, and anthraquinone disulfonic acid. This process was originally designed to remove hydrogen sulfide from synthetic fuel gases, and many Stretford units are operating throughout the world for this purpose. The process is very effective: it removes over 99 per cent of the hydrogen sulfide that enters the system. (DOE 1981).

(b) Control of Liquid Effluents

The volumes of waste liquids and gases from geothermal plants are very large. Even if the plant is temporarily shut down, the wells normally are kept operational, so the waste production is continuous.

Only two basic methods of liquid disposal exist direct discharge (surface disposal) or injection. Both methods have been or are being used at geothermal plants around the world.

Treating the spent geothermal fluid before disposal would reduce the problems of injection or permit direct release for either secondary use or surface drainage. Simple treatments would be settling and filtration or flocculation. More advanced treatments, such as reverse osmosis, electrodialysis, or ion exchange, are sometimes used on liquid wastes from industries other than geothermal. The solids that are generated by the treatment process can themselves present a major disposal problem. The primary considerations, however, will be the cost and the effect of depleting the producing reservoir by not returning the liquids.

3. Small Hydro-Power

The presence of dams in flowing waters can block both the upstream and down stream migration of the fish. A fish ladder, which is a series of pools formed by weirs set at intervals across the ladder channel, is typically used to mitigate this problem. The high cost (up to 5 to 10 per cent of total projects costs) of fish ladders has led developers to seek other approaches to the fish-migration problem. The leading alternative is the portage approach, in which migrating fish are attracted to a location, collected, and trucked to a safe upstream (or downstream) location. Other alternatives (similar to fish ladders) are fish lifts and fish locks. Severe fish mortality from passage through turbines and over spillways or from increased predation in reservoirs can be compensated for by supplemental stocking with hatchery-reared fish.

Changes in upstream water levels and downstream flow-release patterns can alter shorelines, affect recreation, and interfere with fish and wildlife habitats. The latter is of particular concern where a hydropower plant is used for meeting peak power demands. Here, the daily fluctuations may play havoc with the ecosystem especially in flatter areas where marshland supports birdlife. The most effective means of mitigating this problem is to design and operate small-scale hydropower systems as run of the river facilities and meet peak power demands by other means.

The development of small-scale hydropower facilities covers a wide range of possible construction activities, entailing varying degrees of potential environmental impacts and needs for mitigating control techniques. In the redevelopment of existing facilities, various states of repair of dam, powerhouse, and turbogenerating equipment will be found, sometimes in combination with an impoundment whose volume has been significantly reduced by sedimentation and may require extensive dredging. Control techniques for mitigating the environmental impacts of dredging operations are in widespread use of channelization, tunnel and pier construction, and other types of water or wetland-related construction.

Changes in the dissolved-oxygen content of the water downstream of the dam can disturb the downstream habitat of a dam site. Here the addition of a hydraulic turbine may decrease the dissolved-oxygen content of the water, especially for periods of low flow during the summer. Mitigation techniques include multilevel outlet structures and oxygen or air injection.

4. Wind Energy Controls

Most of the controls associated with mitigating the environmental problems of wind generators are passive techniques of design and siting, rather than add-on devices.

(a) Safety

Wind-device safety problems related to structural failure should be solvable by structural design analysis and improvement material research and selection, and appropriate site isolation and marking. New composite and fiberglass materials and metals less susceptible to fatigue, are being tested and advanced computer analyses are being made of these complex structures under load and oscillation. These simulations are also seeking to determine fail-safe modes for the control mechanisms.

Electrical safety problems, including interconnection hazards and lightening, can probably be handled by existing safety devices and procedures: however, the interconnection problem will probably require some unexpected investments and may precipitate conflicts over funding.

If the use of medium and large-scale devices becomes widespread aircraft safety can be ensured only by adequate planning, siting, control and marking. Since the rotor tip could extend hundreds of meters above the tower, appropriate lighting and marking of the rotor is essential.

(b) Noise

The only available techniques for mitigating noise are design and lubrication and appropriate siting. Not only the rotor generator, and tower, but the systems design of the entire mechanism and the control devices needs to be examined. It has been suggested that some low-frequency noises are related to the hunting (oscilating without reaching a stable point) of control systems.

(c) Aesthetics

Appropriate siting and pleasing design are probably the only techniques for minimizing aesthetic problems: however, local participation in site choice and public education could be helpful.

(d) Minor Issues

The bird collision problem can be dealt with either by selecting a site outside major known migration paths or by using various combinations of sound and light to divert birds away from sites. However, some birds will continue to collide with wind devices. There is a potential hazard that birds colliding with small-scale devices might contribute to secondary structural failures.

5. Solar Thermal Systems

Solar thermal systems, in general pose fewer environmental hazards during operation than their fossil-fuel alternatives.

For the most part, careful selection of materials for the intended application and operating environment, together with good design practice, will mitigate potential environmental impacts of solar thermal systems. Problems of reflection and glare from collectors are highly site specific and require different solutions for different installations. Often, however, it will be possible to erect barriers between collectors and nearby roads or population centers. In normal operation, tracking and concentrating collectors let less reflected light escape than do non tracking flat-plate collectors: however, misalignment can result in concentrations of sunlight is unexpected areas and perhaps cause harm.

Accidental spills or leaks of solar-equipment working fluids can be minimized through regular system maintenance and the use of chemical management procedures. The latter may include double-wall designs for water or air heat exchangers to separate the heat-transfer fluid from the process fluid. Site development should include containment ponds or dikes to contain spills or leaks. Careful attention to system operations should include the monitoring and maintenance of working fluids.

For disposal procedures, working fluids can be classified as glycols, silicones hydrocarbons and fluorocarbons.

(a) Glycols

The liquid working fluids most commonly used in solar thermal systems are ethylene and propylene glycol-water mixtures. Both are biodegradable, so sewer disposal should be acceptable for limited quantities. (A reasonable procedure is to dilute the mixture with 10 parts water to 1 part clycol-water before discarding it).

(b) Silicones

If silicone fluids are widely used, recycling is an economical means of disposal. If their use is limited, disposal by carefully controlled incinera-

tion is an acceptable alternative, although if requires special equipment to control particulate emissions. Landfill may also be an acceptable solution for disposal of small quantities of waste silicone oils.

(c) Hydrocarbon Oils

Hydrocarbon working fluids are similar to automotive and industrial oils. Methods presently used to dispose of these waste oils include recycling incineration and road surfacing. Economically desirable techniques are burning for fuel and recycling for petrochemicals.

(d) Gases

Waste fluorocarbons have been disposed of by venting to the atmosphere but this is not considered environmentally acceptable. They could be pumped into storage tanks by maintenance personnel and then recycled or properly disposed of by manufacturers.

6. Power Alcohol (Ethanol)

(a) Production

The growing of corn as the primary feedstock for fuel ethanol is not substantially different from the growing of corn for food or livestock feed.

The main environmental impact of crop production is erosion which degrades water quality via sedimentation. This is non-point-source pollution, since there is no specific discharge point at which control technologies can be applied. Discharges to the environment are made over a wide area, and control is very difficult. For this reason, efforts must be directed toward prevention rather than treatment. In the case of agricultural pollution this means minimizing erosion through better farming techniques. Often, however, techniques that serve to decrease erosion increase the need for agricultural chemicals, namely herbicides and pesticides.

Common methods for controlling erosion include contour or strip farming, terracing, narrow crop rows, winter crop cover, reduced tillage and better timing of farming operations. With contour farming, soil loss can be reduced 30 to 50 percent without a loss in productivity. None of the other methods has as great an erosion-reduction potential, so they are less extensively employed. Narrow crop rows provide more ground cover in a shorter time but require increased fertilizer use. Better timing of farm operations means leaving the ground bare for the minimum possible amount of time.

No-till and reduced-till farming are also methods of decreasing erosion. No-till farming is expected to reduce erosion by 50 to 95 per cent although 15 per cent more fertilizer and 11 to 15 per cent more pesticides

are required. Reduced-till methods are similar, but the ground is worked to some extent, which increases erosion and reduced fertilizer and pesticide needs.

Furrow basins, sprinklers, recycling and better scheduling are some of the methods used to decrease water use and the environmental impacts associated with irrigation. The rising cost of energy is encouraging the implementation of better application methods to help conserve irrigation water.

Environmental control measures associated with the harvesting of crop and forest residues are less defined than those associated with agriculture. In general, careful evaluation of existing conditions and long-term effects before harvesting appears to be the best environmental control.

(b) Processing

In general, hardware for control of various pollutants generated in the production of fuel ethanol from biomass is commercially available. The major capital items include systems for flue-gas scrubbing, wastewater treatment and ash collection: vapor-controlled storage tanks; and vent condensers.

Besides control hardware, certain procedures implemented in the workplace constitute effective environmental control systems. Worker health and safety can be protected by minimizing exposure to chemicals by keeping work areas well-ventilated, and by educating workers to follow proper safety precautions in handling toxic or corrosive chemicals and to wear protective gloves and clothing when appropriate. Wherever any volatile organic compounds are in use, precautions must be taken to prevent ignition of leaks or fumes. For example, explosion-proof motors should be routinely used, along with other specially protected electrical equipment.

Because a fossil-fuel-fired steam generator is one of the major sources of environmental impacts at any alcohol producing plant an obvious environmental control measure is the reduction of the amount of process steam required. A second possible control measure is in the introduction of a less polluting fuel source. Two alternatives, oil and natural gas are not economically practical. Future alternatives might be combusion or gasification of agricultural wastes. Three major approaches to reducing the use of process steam are (1) increasing the efficiency of individual steps in the process, or introducing new process steps to replace conventional steps; (2) reusing so-called waste heat whenever possible and (3) siting plants so as to minimize energy consumption.

Opportunities for effective siting abound in the fuel-ethanol industry. Retrofit of food-processing factories or beverage-ethanol distilleries could bring additional fuel-ethanol production on line quickly but perhaps at some cost in energy efficiency associated with the use of older plants. Proximity to abundant renewable or "waste" heat sources can also influence siting

decisions and achieve production economies. Perhaps the most important consideration in site selection is proximity to feedstock sources.

Although environmental controls for fermentation and anaerobic digestion facilities are well established, further research is necessary to develop control technology for gasification plants. Controls used by the petroleum-refining and coal gasification industries are expected to provide a basis for control of emissions from gasification. Identification and characterization of the environmental impacts of all of the technologies is also required in varying degrees (US/DOE 1981).

(c) Conversion

Health, safety and ecosystem concerns resulting from the use of alcohol fuels should be controlled through revised standards or other procedural changes in their distribution, handling and use. Air require technological solutions. Existing oxidation and new three-way catalysts have been shown to be effective in reducing alcohol-fuel exhaust emissions. Furthermore, since neat ethanol and methanol yield no sulfur compounds and no particulates, the catalysts should not be poisoned and should give prolonged satisfactory service. Evaporative emissions may require improved vapor recovery systems. Vapor recovery systems should be effective at reducing evaporative emissions associated with alcohol/gasoline blends, but improved systems designed for increased flow rates may be needed to deal with neat alcohols. In all cases, these controls are expected to involve only marginal costs and should not appreciably increase the fuel costs (US/DOE 1979 (c)).

TABLE 1: ENVIRONMENTAL IMPACTS OF FUEL EXTRACTION FOR ELECTRICITY GENERATION (PER TW(e)h)

Impacts	Coal	Oil	Natural Gas	Nuclear with no-recycle		Fuelwood	Geothermal	Hydropower	Solar Thermal	Biogas
				SM	UM					
Land Use ha	TC Land 230...2700 (SM) 115...330 (UM)	14 for on-shore wells 8 for pipe-line	5.7 for on-shore wells	TC 11.4... 22.8 0.13 PC		Varies with rotation period	Vap D.13.8 Liq.D.3.7	19...475	91	NA
Water hm^3	0.023(SM) 0.042(UM)	1.7 for on-shore production	Nil	NEA		30.8(for plantation and harvesting)	Nil	NA	0.085	NA
Airborne										
SO_x(t)	0.94	1500	12900	3.4	0.07	61		Nil	Nil	NH_3 may be released during collection
NO_x(t)	14	2000	764	2	1	555	Negligible amounts of H_2S, CO, NH_3			
CO (t)	8.5	57	17.5	0.007	0.66	737.5				
HC (t)	1.9	1200	5.43	0.14	0.1	119				
Particulates	0.19	385	17.5	1.7	0.035	36.5				
Others	Coal dust		H_2S			15kt fugitive dust				
Radioactivity $Rn^{220,222}$										
Rn^{222} Ci	Neglible			112	677					

Impacts	Coal		Oil	Natural Gas	Nuclear with no re-cycle	Fuelwood	Geothermal	Hydropower	Solar Thermal	Biogas
Liquid Waste	SM	UM								
TSS(t)	3.8	176	$80hm^3$ brine	Brine NEA	Drainage water with dissolved and suspended Uranium	11 ha^3 acqueous waste	Nil	Nil	Nil	BOD = 9kt
TDS(t)	197	4100								
Sulphate(t)	135	1800								
Ammonia(t)	0.19	3								
Solid Waste										
Tailings	1100 (SM) 14 (UM)		Neglible	Neglible	148 ... 579	Residuals used as fuel	Nil	Silt precipitate behind dam	Nil	Usually no actual waste
Occupational Health Hazards	SM	UM								
Labour m/y	64	194	33.8	48	10.9 38.2	1800	NA	NA	NA	NEA
Total Fatalities 10^{3} [1/]	14	217	63	11...18	5.7 19.4	200				
Injuries/ Disease	2.1	19.4	5.44	1.8...1.9	(0.34..(0.57.. 0.8) 1.14)					
WDL	82.3	698	113	42.5	10.6 16.3	1400				

Abbreviations: SM – Surface Mining; UM – Underground Mining; NA – Not Applicable; NEA – No Estimates available
WDL – Work Days Lost; TC – Temporarily Committed; PC – Permanently Committed

1/ Figures given are multiplied by 10^3, to get final values divide by 10^3 (e.g. 14 x 10^{-3} for surface mined coal)

Impacts	Coal	Oil	Natural Gas	Nuclear with no recycle	Fuelwood	Geothermal Energy	Hydro-Power	Wind Energy	Solar Thermal	Biogas
Occupational Health Hazards										
Labour m/y	12	28	3.6	19.5 ... 26.6						
Fatalities[3/] x 10^3	570 .. 1000	0.63	0.046 ... 0.34		Refer to Table 1 on Fuel	NA (see conversion Table 3)	NA	NA	NA	See conversion Table
Injuries/ Diseases	0.16	0.83	0.006 ... 0.04	14.8						
WDL	21.3	184	0.1 ... 0.28	55						

Abbreviations: TC - Temporarily Committed; PC - Permanently Committed; DU - Direct Use; EZ - Exclusion Zone; TSS - Total Suspended Solids; TDS - Total Dissolved Solids; BOD - Biological Oxygen Demand; NA - Not Applicable; NEA - No Estimates Available; WDL - Working Days Lost

TABLE 2: ENVIRONMENTAL IMPACTS OF FUEL PROCESSING FOR ELECTRICITY GENERATION (Normalised to 1 Tw(e)h)

Impact	Coal	Oil	Natural Gas	Nuclear with no recycle	Fuelwood	Geothermal Energy	Hydropower	Wind Energy	Solar Thermal	Biogas
Land Use (ha)	9...23(TC) 0.8 (FC)	0.24(DE) 0.24(EZ)	1.37 ... 2(TC)	TC=0.725 FC=0.2	Refer to Table 1 on Fuel Extraction	Refer to Table 1 on Fuel Extraction	Refer to Table 1 on Fuel Extraction	NA	NA	1.1
Water hm^3	2.3 ...57	3 ... 57	3 for cooling and 0.57 for MU	0.9393 ... 0.9713		NA		NA	NA	Recoverable
Airborne										
NO_X(t)	0.016	2600	110	1495	Refer to Table 1 on Fuel	NA (see conversion table 3)	NA	NA	NA	Negligible amount of leaked H_2S from digester Odour could be a nuisance
SO_X(t)	2.4	2200	30	396						
CO(t)	0.8	530	2.4	10.1						
HC (t)	0.8	Organics 3850	2.4	4.4						
Particulates(t)	3.2	338	2.4	390						
Fugitive Dust(t)										
$H_2O(hm)^3$										
Rn^{222}(Ci				0.88						
Ra^{226}(mCi)				1.4						
Th^{230}(mCi)				1.6						
U(mCi)				7.11						
Others		Ammonia 279(t)	Aldehydes 0.3 (t) + Organic (t)	Fluoride 0.72 (t)						

Impacts	Coal	Oil	Natural Gas	Nuclear with no recycle	Fuelwood	Geothermal Energy	Hydro-Power	Wind Energy	Solar Thermal	Biogas
Liquid Waste TSS (t)	2.4	0.12 hm^3 containing oil, grease, phenol, ammonia suspended and dissolved solids and metals	condensate stripper bottoms of which consists mainly of chloride and sulphate	effluent containing toxic substances	Refer to Table 1 on Fuel Extraction	NA (see conversion table 3)	NA	NA	NA	Digester effluent is used as fertilizer or water is recovered and solids are added to sludge
TDS (t)	132									
Sulphate(t)	72									
Ammonia(t)	0.16									
Radio-activity U(mCi)				18.2						
Ra^{226}, Th^{230} (mCi)				0.92						
Rn^{222}(mCi)				28.4						
Solid Waste	About 47 ht of coarse and fine refuse	NEA but no serious environmental impacts are expected	NEA but no serious environmental impacts are expected	Mill tailings 37kt U and daughters 98Ci, Ra^{226}(25 Ci) Th(23 Ci)	Refer to Table 1 on Fuel Extraction	NA	NA	NA	NA	Sludge used as fertilizer

TABLE 3: ENVIRONMENTAL IMPACTS OF FUEL TRANSPORTATION FOR ELECTRICITY GENERATION

Impact	Coal	Nuclear with no recycle	Natural Gas	Oil	Fuelwood	Geothermal Energy	Wind Energy	Solar Energy
Air Pollution	Fugitive coal dust	Radioactivity	H_2S	H_2S	Dust	NA	NA	NA
Water Pollution	Water used in slurry pipelines should be treated before discharge	Radioactivity in case of accident	Spills of LNG in case of accident	Oil spills from routine and accident situation	Nil	NA	NA	NA
Impact on Land	Contamination in case of accident Land area required for pipelines	Radioactive contamination in case of accident	Land area required for pipelines	Oil spills in case of pipeline accidents Impacts of oil spills on coastal areas	Nil	NA	NA	NA
Occupational Health Hazards								
Accidental fatalities x 10^3 2/	1.6 ... 140	1.1	1	5.7 ... 8	48 1/	NA	NA	NA
Radiation induced fatal cancers x 10^3	Nil	0.05		Nil	Nil			
Accidental injuries/disease	0.03 ... 2.3	0.00114	0.14	0.034 ... 0.66	23.3 1/	NA	NA	NA
WDL	36	NEA	2	11.2	NEA	NA	NA	NA

Impact	Coal	Nuclear with no re-cycle	Natural Gas	Oil	Fuelwood	Geothermal Energy	Wind Energy	Solar Energy
Radiation induced non fatal cancers 140 2/	Nil	0.063	Nil	Nil	Nil			
Public Health Hazards								
Fatal cancers 110 3 2/		0.05						
Non fatal cancers 110 3 2/		0.053						

1/ Morris (1981).

2/ Accident fatalities are multiplied by 10^3 or 10^5. Divide by 10^3 to get final figures (e.g. 1.6 ... 140 x 10^{-3}).

Abbreviations: NA - Not Applicable; NEA - No Estimates Available; WDL - Working Days Lost.

TABLE 4: ENVIRONMENTAL IMPACTS OF FUEL CONVERSION INTO ELECTRICITY AT THE POWER PLANT
(Normalized to ITW (e) h)

Impacts	Coal	Oil	Natural Gas	Nuclear with no recycle	Fuelwood	Geothermal Energy	Hydro-Power	Wind Energy	Solar Thermal	Biogas
Land (n)	1.9 ... 2.5	0.4 ... 0.72	0.2...0.42	0.23 ... 0.29 113 (EZ) 7000 (LTZ)	2.97	3.4	Included in reservoir area	Given in connection with extraction	Given in connection with extraction	0.2 ... 0.42
Water hm^3	120 for cooling 0.258 for MU	120 for cooling 0.258 for MU	120 for cooling 0.258 for MU	222 for cooling 0.44 for Mu	120 for cooling 0.258 for MU	3.6 for MU for cooling tower if used		Nil	0.085 for process and maintenance	120 for cooling 0.258 for MU
Airborne						VDS LDS				
SO_x (t)	12800	4200	2.3...2.5		390	H_2S(t) 26.5 12 ... 120	H_2O	Nil	Nil	1170 ... 2320
NO (t)	3000	2850			1170 ... 5800	NH_3(kt 0.25...5.6 0.46 ... 47				1140
CO (t)	230	81	70		235	CO_2(kt) 26 18.7 ... 187				
HC (t)	46	54	4		765	H_3(t) 0.13 6.24				
Particulates(t)	900	137	58...132		2600 ... 3500	Boron(t) 0.259 31 ... 313				CO_2(kt) 35(t) H_2S(kt)
Others	1.1Mt CO_2	Aldehydes 27t		PWR BWR	Aldehydes(190-630)t	Particulates(t) 21 33 ... 49 Ci	NEA 127(1028) Ci			568 .. 1136
Radio-Activity	11.4 mCi(Ra)	0.12 mCi (Ra,Rn, Th		X_e(Ci) 1500 Kr(Ci) 93 H^3(Ci) 24 C^{14}(Ci) 0.7 I(mCi) 16.5	10500 6060 10 1.6 1480	Rn^{222} 127 Ci	33 ... 49 Ci			

Impact	Coal	Oil	Natural Gas	Nuclear with no recycle	Fuelwood	Geothermal Energy	Hydro-Power	Wind Energy	Solar Energy	Biogas
Liquid Waste										
TSS(t)	57	57	57	Depends on flow		If not reinjected into geothermal reservoir brine will represent a serious problem	NA	Nil	Boiler blow down may contain hydrocarbon oils, corrosion inhibitors, pH controls etc.	9750
TDS(t)	457	1196	200							
BOD(t)	0.27	0.3 ... 16	0.3... 1.2	0.31						9000
Organics(t)	8.5	7.5	7.5	8.93	5000					
Chromates(kg)	0.2	228	228	310						
H_2SO_4(t)	9.4	9.4	9.4	11.1						
Cl_2 (t)	3	3	3	3.2						
Boron(t)	38	38	38	45						
Phosphate(t)	4.8	4.6	4.8	5.1						
Waste Heat TWh	1.27	1.27	1.27	2	2.4		NA	Nil	1.5 ... 12.15	About 1.27
Radioactivity				2046 Ci						
Solid Waste										
Main contents	Ash	Flyash	Nil	Spent fuel 4.04(t)U, 0.04(t)Pu	55t of TOM in 6kt of ash	600m^3 of sludge	NA	Nil	Nil	Filer cake contains varying amounts of metal trace (Zi, Cu)
Amount(t)	41000	1050								
Radioactivity (Ci)	Ra^{226} Ra^{228} 0.1	(Ra,Th 0.0003		Estimated Radioactivity 1.6 MCi from spent fuel and 580 Ci from waste		Nil	NA	Nil	Nil	

Impacts	Coal	Oil	Natural Gas	Nuclear with no recycle		Fuelwood	Geothermal Energy	Hydro-Power	Wind Energy	Solar Energy	Biogas
Occupational Health Hazards				NF[1/]	WM[1/]						
Labour m/y	37	31.7	37	133		82.5	16.95	17.1	120	239	170.8
Fatalities x 10^{3}[2/]	3.4 ... 50	1.50 ... 2.30	1 ... 2	16.50	0.053	40	38	0.65... 3.3	10.06	74	42
Injuries/ disease incidents x 10^{3}[2/]	460 ... 680	170 ... 1630	130 ... 1830	168	0.06		200				
WDL	17 ... 25	2.8 ... 31	2.2 ...31	2.8	2.5	22.1	4.51	0.02	137	269	152

1. Abbreviations used: CT - Cooling Tower; EZ - Exclusion Zone; LFZ - Low Population Zone; MU - Make-up; POM - Polycyclic Organic Matters; HLW - High Level Waste; NF - Nuclear Power Plant; WM - Waste Management Plant; RP - Reprocessing Plant; VDS - Vapour Dominated Systems; LDS - Liquid Dominated System; PWR - Presurized Water Reactor; BWR - Boiling Water Reactor.

2. Figures given in table are multiplied by 10^{3}. To get final values divide by 10^{3} (e.g. 3.4 ... 50 x 10^{-3})

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